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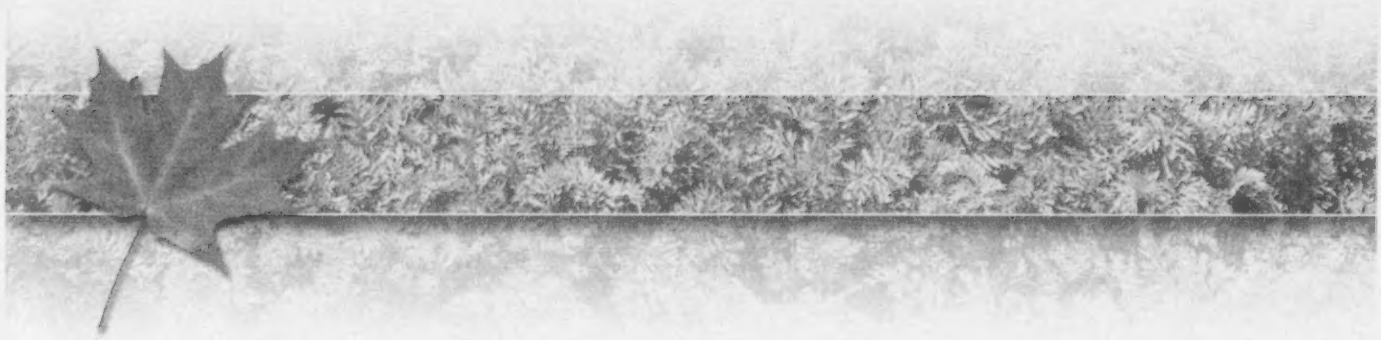

Crop Profile for Carrot in Canada, 2012

Prepared by:

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Canada

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Preface

National crop profiles are developed under the Pesticide Risk Reduction Program (PRRP), a joint program of Agriculture and Agri-Food Canada (AAFC) and the Pest Management Regulatory Agency (PMRA). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique, discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing carrots, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

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Crop Profile for Carrot in Canada

The carrot (*Daucus carota*) is a member of the Apiaceae (formerly Umbelliferae), the parsley family). Carrots are biennial plants, but they are grown as an annual crop and harvested for the enlarged taproot. Wild carrots were consumed in prehistoric times, and are believed to have originated in the area around what is now Afghanistan. They were put to medicinal and herbal uses, but were not generally eaten for food because of their poor flavour. Described in Greek and Roman literature, by 900 AD carrots were grown from India to the Eastern Mediterranean. By 1300 the range of cultivation had extended to include China and Western Europe. Today there are hundreds of varieties but orange carrots were not known until the 17th century, when they were developed in Holland. Orange carrots are now the predominant type on the world market, but coloured varieties are making a comeback. Carrots are an excellent source of beta-carotene (pro-vitamin A). Carrots can also be used to produce food colouring, for example, used in colouring dairy products. Other nutrients contained include vitamin C, vitamin B6, and folic acid as well as potassium. Carrots may be consumed fresh, cooked, or juiced.

Crop Production

Industry Overview

Carrots are grown for both the fresh market and processing industries and are a crop of high per capita consumption. Fresh carrots can be sold as either "bunched" (with tops) or "topped" (without tops). Increasingly popular in the late 90's are "baby carrots", which took over large parts of the traditional topped carrot market. Many of these pre-packaged, washed, ready to eat baby carrots may be cut from undersized carrots or pieces of larger carrots, but they generally are grown from selected cultivars at high density. Since they undergo minimal change to the actual carrot, baby carrots are not considered to be processed. Processing includes canning and freezing.

Table 1. General production information

Canadian production (2012)[1,2]	400,795 metric tonnes 8,610 hectares
Farm gate value (2012)[1,2]	$87 million
Fresh carrots available for consumption in Canada 2012[3]	8.85 kg/ person
Export (2012)[3]	$39 million
	91,526 metric tonnes
Imports (2012)[3]	$114 million
	117,347 metric tonnes

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database). (Accessed: 2014-05-13)

[2]Includes baby carrots and regular carrots

[3]Agriculture and AgriFood Canada. Statistical Overview of the Canadian Vegetable Industry, 2012. AAFC no. 12162E-PDF

Production Regions

Carrots are grown in all regions of Canada, being a cool season vegetable adapted to long, cool growing seasons. The majority of carrot production occurs in Ontario (43%) and Quebec (32%), both for fresh market and processing.

Table 2. Distribution of carrot production in Canada (2012)[1,2]

Production Regions	Planted Area 2012 (hectares)	Percent National Production
British Columbia	173[3]	2%
Alberta	136	2%
Saskatchewan	9	<1%
Manitoba	F[4]	-
Ontario	3,686	43%
Quebec	2,779	32%
New Brunswick	52	1%
Nova Scotia	872	10%
Prince Edward Island	499	6%
Newfoundland	59	1%
Canada	8,610	100%

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed: 2014-01-21).

[2]Includes baby carrots and regular carrots.

[3]Use with caution.

[4]Too unreliable to be published.

Figure 1. Common zone map: North American major and minor field trial regions[1,2]

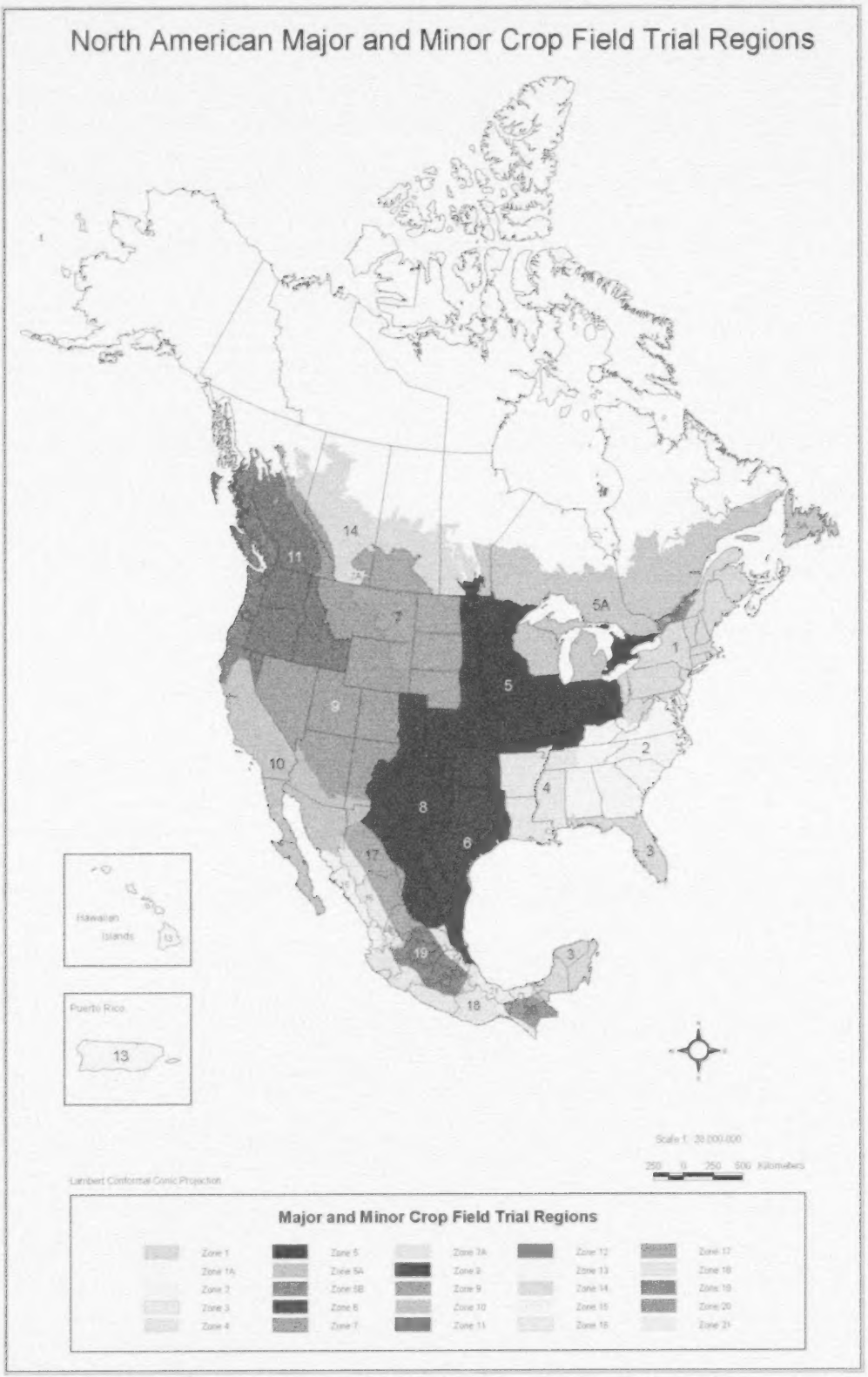

Figure 1. Common zone map: North American major and minor field trial regions[1,2]

The major and minor crop field trial regions were developed following stakeholder consultation and are used by the Pest Management Regulatory Agency (PMRA) in Canada and the United States (US) Environmental Protection Agency to identify the regions where residue chemistry crop field trials are required to support the registration of new pesticide uses. The regions are based on a number of parameters, including soil type and climate but they do not correspond to plant hardiness zones. For additional information, please consult the PMRA *Regulatory Directive 2010-05 Revisions to the Residue Chemistry Crop Field Trial Requirements* (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

[1]Produced for: *Asociación Mexicana de la Industria Fitosanitaria, A.C.*

[2]Produced by: Spatial Analysis and Geomatics Applications, Agriculture Division, Statistics Canada, February 2001.

Cultural Practices

The best soils for growing carrots are well-drained, stone-free, organic, peat and sandy loam soils with good water holding capacity. Most of the Canadian carrot crop is grown in organic soils. In Ontario, carrot acreage grown in highland or non-organic soils is rapidly increasing and almost equalling muck production. Carrots are grown in temperate regions of the world and in tropical areas where high elevations give cool night temperatures. Optimum growing temperatures for carrots are 15° to 20°C, with a minimum of 5°C and a maximum of 24°C. In Canada, carrots are planted from mid-March to June. Carrots take from 6-21 days to germinate, and from 70 to 120 days to fully mature. The optimum temperature for germination ranges from 10° to 25°C. Carrot foliage is frost sensitive, but this does not usually damage the roots. Prolonged frost over 24 hours may injure the crowns and the carrots will not keep in storage.

Carrot harvest begins with the bunched crop in mid-July. Roots for topping and packaging are harvested later, starting in early to mid-August. Carrots harvested from mid-September to November can yield a gross weight of 40 tonnes to 80 tonnes per hectare. However, marketable yields average 25 tonnes per hectare (fresh or processed). Carrots are mechanically harvested by undercutting roots and lifting them out of the soil and into the machine by grasping the leaves. It is important to maintain healthy leaves until the carrots are harvested.

Table 3. Carrot production and pest management schedule in Canada

Time of year	Activity	Action
November - April	-	Nothing done
May	Plant care	Seeding (earlier in some areas)
	Soil care	Fertilization and cultivation
	Disease management	Seed treatment
	Insect & mite management	Seed treatment
	Weed management	Cultivation and pre-emergence sprays
June	Plant care	Irrigation and monitoring
	Disease management	Monitoring and spraying when necessary
	Insect & mite management	Monitoring and spraying when necessary
	Weed management	Post emergence sprays
July - August	Plant care	Irrigation and monitoring
	Disease management	Monitoring and spraying when necessary
	Insect & mite management	Monitoring and spraying when necessary
	Weed management	Limited
September - November	Plant care	Harvesting (later in some areas) and storage
	Disease management	Limited so late in the season
	Insect & mite management	Monitoring and spraying when necessary
November - February	-	Storage

Abiotic Factors Limiting Production

High Temperatures

Carrots are best adapted to long cool growing seasons. Carrots have a low tolerance for high temperatures. During hot, bright, sunny days, young plants can be badly injured or killed by high temperatures that develop at or just below the soil surface. Prolonged hot weather later in the development of the plants may not only retard growth and depress yield, but also may cause undesirable strong flavour and coarseness in the roots.

Drought

Carrots have a low tolerance to drought. Carrots are most sensitive to moisture stress during root enlargement and seed germination. Irrigation can improve emergence, reduce wind erosion and lower temperatures at the soil line during germination.

Diseases

Key issues

- There is a need for the registration of reduced risk products for alternaria blight that are compatible with integrated pest management programs, to enable rotation and resistance management.
- There is a need for expanding the availability of forecasting models developed by the Computer Centre for Agricultural Pest Forecasting (CIPRA) and weather monitoring for forecasting foliar blights of carrot, across Canada.
- There is a need to implement an effective monitoring program for aster leafhoppers to mitigate the risks of crop loss caused by the aster yellows phytoplasma, for future years.
- Work is required to develop effective approaches to manage Rhizoctonia crown rot and cavity spot, rusty root and root dieback caused by *Pythium* spp.
- There is a need for the development of an integrated approach to the management of nematodes in carrots that includes effective crop rotations and non-chemical solutions.

Table 4. Occurrence of diseases in carrot production in Canada[1,2]

Disease	Alberta	Ontario	Quebec	Nova Scotia	Prince Edward Island
Sclerotinia rot (white mould)					
Grey mould					
Alternaria blight					
Cercospora blight					
Bacterial leaf blight					
Crater rot					
Violet root rot					
Crown rot					
Aster yellows					
Cavity spot					
Pythium root dieback (rusty root)					
Crown gall					
Nematodes					
Root lesion nematode					
Northern root knot nematode					
Sour rot					
Bacterial soft rot					

Widespread yearly occurrence with high pest pressure.
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.
Pest is present and of concern, however little is known of its distribution, frequency and importance.
Pest not present.
Data not reported.

[1]Source: Carrot stakeholders in reporting provinces.

[2]Please refer to Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices in carrot production in Canada[1]

Practice / Pest		Sclerotinia rot (white mould)	Cercospora and alternaria leaf blights	Crater rot	Cavity spot	Nematodes
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	reducing mechanical damage or insect damage					
	thinning / pruning					
	use of disease-free seed, transplants					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding / planting depth					
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / elimination of infected crop residues					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					
Monitoring	scouting - trapping					
	records to track diseases					
	soil analysis					
	weather monitoring for disease forecasting					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					

...continued

Table 5. Adoption of disease management practices in carrot production in Canada[1] (continued)

Practice / Pest		Sclerotinia rot (white mould)	Cercospora and alternaria leaf blights	Crater rot	Cavity spot	Nematodes
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	controlled atmosphere storage					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific practices	Trimming of carrot foliage to reduce disease development					

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Seed treatments						
fludioxonil	phenylpyrrole	E2: signal transduction	MAP/Histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	RE	Seedling diseases due to *Fusarium* spp., *F. graminearum*, *Rhizoctonia* spp., *Aspergillus* spp. and *Penicillium* spp.
metalaxyl-M	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	Pythium damping-off
thiram	dithio-carbamate and relative	Multi-site contact activity	Multi-site contact activity	M3	RE	Seedling blight, damping-off
Soil treatments						
Bacillus subtilis strain QST 713	Bacillus subtilis and the fungicidal lipopeptides they produce	F6: lipids and membrane synthesis	microbial disrupters of pathogen cell membranes	44	R	Rhizoctonia root rot, black scurf and stem canker, phytophthora root rot and pink rot (*P. erythroseptica*), pythium root rot and cavity spot, fusarium root rot
Coniothyrium minitans	biological	unknown	unknown	N/A	R	Application to soil or to harvest residues for suppression of *Sclerotinia sclerotiorum*
Pre-plant soil fumigation						
chloropicrin (Restricted) (root and tuber vegetables)	chloropicrin	Miscellaneous non-specific (multi-site) inhibitors	Miscellaneous non-specific (multi-site) inhibitors	8B	RES*	Root knot and root lesion nematodes; soil-borne disease organisms such as *Phytophthora* spp., *Verticillium* spp., *Thielaviopsis* spp., *Fusarium* spp. and *Pythium* spp.

...continued

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatments						
azoxystrobin	methoxy-acrylate	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Rhizoctonia root rot, crown rot and stem canker; seed rot/ pre-emergence damping-off caused by *Rhizoctonia solani*
azoxystrobin + difenoconazole	methoxy-acrylate + triazole	C3. respiration + G1: sterol biosynthesis in membranes	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14-demethylase in sterol biosynthese (erg11/cyp51)	11 + 3	R + RES	Leaf blight (*Alternaria dauci*), cercospora leaf spot (*Cercospora carota*)
Bacillus subtilis strain QST 713	Bacillus subtilis and the fungicidal lipopeptides they produce	F6: lipids and membrane synthesis	microbial disrupters of pathogen cell membranes	44	R	*Sclerotinia sclerotiorum*
boscalid	pyridine carboxamide	C2. respiration	complex II: succinate-dehydro-genase	7	R	Alternaria leaf blight (*Alternaria dauci*)
boscalid + pyraclostrobin	pyridine carboxamide + methoxy carbamate	C2. respiration + C3 respiration	complex II: succinate-dehydro-genase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	Alternaria leaf blight (*Alternaria dauci*)
chlorothalonil	chloronitrile (phthalonitrile)	Multi-site contact activity	Multi-site contact activity	M5	RE	Early blight (*Cercospora* spp.), late blight (*Alternaria* spp.)
copper, present as basic copper sulfate	inorganic	Multi-site contact activity	-	M1	R	Cercospora leaf spot

...continued

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatments						
cyazofamid	cyano- imidazole	C4. respiration	complex III: cytochrome bc1(ubiquino-ne reductase) at Qi site	21	R	Cavity spot, root dieback/ forking (*Pythium* spp.) (suppression only)
cyprodinil + fludioxonil	anilino-pyrimidines + phenylpyrrole	D: amino acids and protein synthesis + E2 signal transduction	D1: methionine biosynthesis (proposed) (cgs gene) + MAP/Histidine-kinase in osmotic signal transduction (os-2, HOG1)	9 + 12	R + RE	Alternaria leaf blight (*Alternaria dauci*), botrytis gray mold (*Botrytis cinerea*)
fenamidone	imidazolinone	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Damping off and cavity spot caused by *Pythium* spp.
fluazinam	2,6-dinitroaniline	C5. respiration	uncouplers of oxidative phos-phorylation	29	RES	White mold (*Sclerotinia sclerotiorum*), alternaria leaf blight (*Alternaria dauci*)
mancozeb	dithio-carbamate and relatives	Multi-site contact activity	-	M3	RE	Leaf spot diseases, alternaria and cercospora blights
metalaxyl-M	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	Cavity spot (*Pythium* spp.)
metiram	dithio-carbamate and relatives	Multi-site contact activity	-	M3	RE	Alternaria and cercospora blights
penthiopyrad	pyrazole carboxamide	C. respiration	complex II: succinate-dehydrogenase	7	R	Gray mold (*Botrytis cinerea*)

...continued

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatments						
pyraclostrobin	methoxy-carbamate	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Alternaria, cersospora , powdery mildew
thiram (seed treatment)	dithio-carbamate and relative	Multi-site contact activity	-	M3	RE	Seedling blight, damping-off
trifloxystrobin	oximino acetate	C. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Leaf blight (*Alternaria* spp.), cersospora leaf spot (*Cercospora carotae*)

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 5, 2014. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2013: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review as published in the PMRA *Re-evaluation Note REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

White mould *(Sclerotinia sclerotiorum)*

Pest information

Damage: Infected tissue becomes soft and watery. Infection may not be apparent at harvest but can show up in storage where it is spread rapidly from infected carrots to healthy ones. Significant yield losses are possible when growing seasons are cool and wet.

Life cycle: The fungus has a wide host range, including most vegetable crops. The fungus is soilborne and can survive in the soil for many years in the form of sclerotia. Sclerotia germinate when exposed to adequate soil moisture and moderate temperatures. The carrot crop canopy creates an excellent environment for the germination of sclerotia and disease development, with dense foliage that blocks out sunlight and keeps the soil moist. Germination produces apothecia which release ascospores into the air. The ascospores are carried by wind to host plants where they can infect leaves and roots. Infections give rise to fungal mycelium which grows on senescent leaves. The mycelium, through contact, can infect other leaves and is another mode of transmission. In storage, the disease spreads from infected carrots to adjacent healthy roots by mycelial growth.

Pest information

Cultural control: Other susceptible crops should not be grown in proximity to carrot fields. Areas with poor drainage and frequent light watering should be avoided. A 3-4 year crop rotation is important, avoiding beans, cucurbits, celery and cabbage. Soil should be well drained and watering should be done early in the day. Weed control is important and the removal and destruction of infected plant material can help reduce the spread. If late season carrot varieties are used, row spacing should be increased. A new technology, the carrot foliage trimmer has proven successful in reducing disease levels and the amount of fungicide required for disease control. The carrot trimmer is used to trim foliage at about the time of row closure. This practice makes the micro-climate in the crop canopy less conducive to white mould development.

Resistant cultivars: There are several varieties that are less susceptible, however none are resistant.

Chemical control: Field spraying is effective only if the spray contacts lower leaf petioles and crowns. Fungicides registered for use against white mould are listed in table 6.

Issues for white mould:

1. A replacement for benomyl is a priority for both control in the field and storage. Reduced risk or biological products to control white mould in storage are especially needed.

Grey mould (*Botrytis cinerea*)

Pest information

Damage: Affected tissue can develop an extensive soft rot.

Life cycle: The fungus overwinters in plant debris and soil as sclerotia. Conidia, produced in infected crop residue and plants and from sclerotia, are the primary means the disease is spread. Mycelium can also infect healthy plant tissue. The disease thrives in cool moist conditions. Conidia are produced in infection sites 2-3 days after primary infection and are the means of secondary spread.

Pest management

Cultural control: Areas of poor air circulation should be avoided. A 3-4 year crop rotation is beneficial, avoiding beans, cucurbits, celery and cabbage. Plants should be seeded into well drained soil and any watering should be done early in the day. Weed control is very important to minimize disease. The removal and destruction of infected plant material can help reduce the build-up of inoculum in the soil. Row spacing should be increased when late season varieties are used.

Resistant cultivars: None available

Chemical control: Fungicides registered for use against grey mould are listed in table 6.

Issues for grey mould

1. A replacement for benomyl is a priority for control both in the field and storage. In particular, reduced risk or biological products are especially needed to control grey mould in storage.

Cercospora blight (*Cercospora carotae*)

Pest information

Damage: The pathogen causes circular tan spots on the leaves and petioles of carrot which eventually coalesce and kill leaflets. Petiole infections can weaken carrot tops, making harvesting by machinery impossible.

Life cycle: The pathogen affects only the leaves and not the edible carrot root. The fungus overwinters in infected plant debris and wild hosts or is seed borne. Spores are produced on debris and are carried by wind or water to young carrots. The fungus enters the leaves through the stomata, with lesions appearing 3-5 days after infection. Lesions produce new spores in a short period of time, which cause secondary infection. Long periods of leaf wetness provide ideal conditions for infection, but spores are able to germinate over a wide range of conditions.

Pest management

Cultural control: Only disease free seed should be used and resistant cultivars should be chosen. A 2-3 year rotation helps reduce inoculum build-up in the soil. In the fall, residue left after harvest should be ploughed under to speed up decomposition. Over-watering should be avoided and row spacing should be increased for late season varieties. In British Columbia, an IPM program recommends applying fungicides when 25% of mid-age leaves have one or more blight lesions, which corresponds to about 1-2% of the entire field's leaf area.

Resistant cultivars: Resistant varieties include Delite, Delux, Fancy, Bonus, Classic, Winner and Premium.

Chemical control: Fungicides registered for use against cercospora blight are listed in table 6.

Issues for cercospora blight

1. There is a need for expanding the availability of forecasting models developed by the Computer Centre for Agricultural Pest Forecasting (CIPRA) and weather monitoring for forecasting blight across Canada.

Alternaria blight *(Alternaria dauci)*

Pest information

Damage: Alternaria blight primarily affects leaflets and causes brown lesions along leaf margins that often coalesce causing leaflets to shrivel. The disease commonly develops later in the season on older foliage.

Life cycle: Alternaria overwinters in infected debris in the soil and is also spread on contaminated seed. During the growing season, alternaria spores and mycelium are spread by wind, water, splashing rain and farm equipment. The pathogen attacks older foliage and occurs somewhat later in the season than cercospora blight. Damaged plants and nitrogen deficient plants are more susceptible to infection.

Pest management

Cultural control: Treated, disease free seed of resistant varieties should be used if possible. A 3 year crop rotation in well drained soils can help reduce inoculum build-up. Equipment should be cleaned before moving between fields to reduce the spread of inoculum. Fall ploughing will help infected debris decompose more quickly. Fields should be monitored closely and regularly for foliar disease. Blight forecasting models are available to assist with timing of fungicide sprays.

Resistant cultivars: Resistant varieties include Orlando Gold and Hi-color.

Chemical control: Fungicides registered for use against alternaria blight are listed in table 6.

Issues for alternaria blight

1. Reduced risk products are needed to fit in with IPM systems and enable rotation and resistance management.
2. There is a need for a blight forecasting technology.

Violet root rot, storage rot and crater rot (*Rhizoctonia* spp.)

Pest information

Damage: Violet root rot causes lesions on roots and violet, leathery roots. Soil readily adheres to affected roots. The disease develops in patches in the field. Crater rot develops in storage.

Life cycle: Once the pathogen is in the soil, it remains there indefinitely, overwintering as mycelium or in infected plant material. Contaminated soil facilitates the spread of the pathogen from one field to another. Foliar symptoms, such as wilting and dying, are not always obvious until the disease is very serious.

Pest management

Cultural control: Planting in fields with a history of violet root rot should be avoided. Sanitation practices are very important to prevent the spread of the disease to other fields. Disease free seed should be planted as soon as possible in the spring to allow for early emergence and a long crop rotation should be followed.

Resistant cultivars: None available

Chemical control: Fungicides registered for use against rhizoctonia diseases are listed in table 6.

Issues for violet root rot, storage rot and crater rot

None identified

Pythium root dieback (*Pythium* sp.)

Pest information

Damage: Symptoms of pythium root dieback include a rusty discolouration of lateral roots and forking and stunting of tap roots.

Life cycle: Spores are transported by water to the host. The pathogen survives on dead plant and animal matter, but is also able to survive on living plants in wet soils. Mature plants are able to resist infection, however, seeds and young seedlings are much more susceptible. Young roots can be attacked at any stage of plant growth.

Pest management

Cultural control: Dense seeding and planting into severely infested fields should be avoided. Poorly drained soils should be avoided. Seeds should be planted when soil has warmed and resistant cultivars should be used whenever possible. A three year crop rotation including potato, onion, corn and cabbage can reduce infection.

Resistant cultivars: Among the several cultivars that have high tolerance to the pathogen are Spartan Fancy, Canada Super X, Orlando Gold and Paramount.

Chemical control: Fungicides registered for use against pythium diseases are listed in table 6.

Issues for pythium root dieback

1. Pythium root dieback can cause significant crop loss. Work is required to develop effective approaches to manage this disease (eg. effective seed treatments).

Cavity spot (*Pythium* spp.)

Pest information

Damage: The disease rarely reduces yield, but can have significant effects on quality. Roots have elliptical lesions on the surface that are horizontally elongated and darken with age. There are no foliar symptoms. Horizontal lesions up to 10 mm in diameter may develop on roots later in the season.

Life cycle: Symptoms are normally seen on carrots that have been growing for at least 12 weeks.

Pest management

Cultural control: Carrots should not be planted in soils with a history of cavity spot. Excessive moisture and over watering should be avoided. Resistant cultivars should be used and seeds should be planted on raised beds to reduce excessive soil moisture.

Resistant cultivars: Among the many resistant cultivars are Orlando Gold, Six Pak and Spartan Premium.

Chemical control: Fungicides registered for use against pythium diseases are listed in table 6.

Issues for cavity spot

1. Work is required to develop effective approaches to manage this disease.
2. Some fungicides are registered for the control of cavity spot. Further testing is required to assess the cost-benefits of their use.

Crown rot (*Rhizoctonia solani*)

Pest information

Damage: R. solani can cause seedling damping off early in the season. The disease causes horizontal, dark brown lesions to develop near the top of the root that may penetrate several millimetres deep. As the season progresses, rot may develop at the crown of the plant and the tops of plants may die.

Life cycle: The pathogen survives for many years in soil.

Pest management

Cultural control: Crop rotations and good drainage are both important. Avoiding late harvests and grading carrots before storage can reduce losses.

Resistant cultivars: None available.

Chemical control: Fungicide treatments to prevent damping off can be used. Fungicides registered for use against crown rot are listed in table 6.

Issues for crown rot

1. There is a need to work on solutions to control rhizoctonia in the field.

Aster yellows (Phytoplasma)

Pest information

Damage: The disease is characterized by a yellowing of the leaves and vein clearing at the center of the crown. Crown growth is short, bunchy and brittle. Carrots become deformed and dwarfed and have poor flavour. The pathogen also pre-disposes plants to other diseases, such as soft rot. Severe yield losses are possible, as the disease affects both above and below ground parts of the plant.

Life cycle: Various species of leafhoppers spread the pathogen and the phytoplasma can overwinter in leafhoppers. Overwintering can also take place in perennial host plants, such as weeds and ornamentals. After acquiring the pathogen, 10 days are required before leafhoppers are able to transmit the disease to new plants. An insect may remain active and continue to spread the disease for more than 100 days after acquiring the pathogen. Symptoms become visible 10-21 days after infection. The occurrence of the disease in carrots is directly related to the flight of leafhopper insects from areas with diseased plants to new plantings of carrots.

Pest management

Cultural control: Weed control is very important in the field, as well as in adjacent fields and ditches. Carrots should not be planted near lettuce or other susceptible crops. Early planting is important to establish plants before infection is a concern. Monitoring of insects and their migrations from field to field is important for early season vectors. Scouting is done using sweep nets and sticky traps.

Resistant cultivars: Less susceptible varieties can be chosen to minimize damage.
Chemical control: Refer to table 9 for insecticides registered for control of the aster leafhopper. The disease cannot be controlled with pesticides once a plant is infected.

Issues for aster yellows

1. There is a need to implement an effective monitoring program to mitigate the risks of crop loss for future years.

Root lesion nematode (*Pratylenchus* spp.)

Pest information

Damage: Root lesion nematodes feed on the roots of carrot causing yellowing and wilting of foliage. Affected tap roots are undersized and become branched and lateral roots are killed.
Life cycle: Eggs are laid in soil or root tissues. Upon hatching, juvenile nematodes feed on plant cells killing plant tissues and providing entrance sites for rots. The life cycle form egg to adult can take from 5-12 weeks depending on temperature and moisture.

Pest management

Cultural control: Soil from fields suspected to be infested should be tested for nematodes.
Resistant cultivars: None available.
Chemical control: Refer to table 6 for chemicals registered for nematode control.

Issues for root lesion nematode

1. Root lesion nematodes are of concern as there are few controls available and they can be a serious problem for carrot production.
2. There are few chemicals available to control nematodes.
3. Currently, crop rotation and the control of weeds are important methods for controlling nematodes. Research is needed on the impact of crop rotation and antagonistic plants to battle the nematode.

Northern root knot nematode (*Meloidogyne hapla)*

Pest information

Damage: Nematodes feed on root tips and rootlets, affecting foliage growth and weight and length of roots. The pest causes malformation of the edible root, including forking, galling and hairiness. Severe infections may result in decomposition by secondary pathogens. A loss in stand will occur if seedlings are attacked. Older, infected plants will appear stunted and chlorotic and have a tendency to wilt. Damage levels can be high even when nematode populations are low.

Life cycle: The pest is a microscopic, plant parasitic roundworm found in the soil. Juvenile nematodes enter root tips and feed on plant cells. As they mature, they move through the roots and establish other feeding sites in the vascular tissue. Feeding results in gall formation and other root distortions. When mature, females lay eggs on the surfaces of galls. Nematodes spread mainly by surface water drainage, blowing soil and farm equipment.

Pest management

Cultural control: Crop rotation using non-host crops, such as corn and cereals is important.
Resistant cultivars: None available.
Chemical control: Soil fumigation is effective. Refer to table 6 for chemicals registered for nematode control.

Issues for root knot nematode

1. Nematodes are of concern as there are few controls available and they can be a serious problem for carrot production, especially in muck soils.

Insects and Mites

Key issues

- There is an urgent need for new chemical controls for the carrot weevil.
- Continued work is required on biological controls for carrot weevil.
- There is a need for low risk replacement products as well as products with new chemistry for the control of the carrot rust fly.
- Additional research is required to develop cost effective, alternative, cultural control methods for the carrot rust fly such as row covers, exclusion fences, sterile flies, baits and deterrent products.
- Wireworms are a serious concern with no effective insecticides available for their control. There is a need for new, reduced risk products for wireworm control in many root vegetable crops and for alternative strategies to control wireworms.

Table 7. Occurrence of insect pests in carrot production in Canada[1,2]

Insect	Alberta	Ontario	Quebec	Nova Scotia	Prince Edward Island
Aster leafhopper					
Carrot weevil			D		
Carrot rust fly			D		
Cutworms					
Wireworms					
Widespread yearly occurrence with high pest pressure.					
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.					
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.					
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.					
Pest not present.					
Data not reported.					

D - Data on distribution was not available.

[1]Source: Carrot stakeholders in reporting provinces.

[2]Please refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect pest management practices in carrot production in Canada[1]

	Practice / Pest	Aster leafhopper	Carrot weevil	Carrot rust fly	Cutworms	Wireworms
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	reducing mechanical damage					
	thinning / pruning					
	trap crops / perimeter spraying					
	physical barriers					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding depth					
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / removal of infested material					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					
Monitoring	scouting - trapping					
	records to track pests					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
	grading out infected produce					

...continued

Table 8. Adoption of insect pest management practices in carrot production in Canada[1] (continued)

Practice / Pest		Aster leafhopper	Carrot weevil	Carrot rust fly	Cutworms	Wireworms
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model (eg. degree day modelling)					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	beneficial organisms and habitat management					
	ground cover / physical barriers					
	pheromones (eg. mating disruption)					
	sterile mating technique					
	trapping					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 9. Insecticides and bioinsecticides registered for disease management in carrot production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
carbaryl	Carbamate	Acetylcholinesterase inhibitors	1A	RES*	Flea beetles, leafhoppers, armyworms, cabbbage looper, corn earworm, diamondback moth, imported cabbageworm, lygus bugs, meadow spittlebug, stink bugs, six-spotted leafhopper
chlorantraniliprole	Diamide	Ryanodine receptor modulators	26	R	Diamondback moth, cabbage looper, black cutworm, imported cabbageworm, Swede midge, corn earworm, European corn borer tobacco hornworm, tomato hornworm, armyworm, variegated cutworm, fall armyworm, beet armyworm, leafminers
chlorpyrifos	Organophosphate	Acetylcholinesterase inhibitors	1B	RE	Black cutworm, darksided cutworm, redbacked cutworm
cypermethrin	Pyrethroid, pyrethrin	Sodium channel modulators	3A	RE	Carrot rust fly
diazinon	Organophosphate	Acetylcholinesterase inhibitors	1B	PO by Dec. 31,2016; RES	Carrot rust fly, aphids
flonicamid	Flonicamid	Selective homopteran feeding blockers	9B	R	Aphids
imidacloprid	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	RE	Aphids, leafhoppers, flea beetles, European chafer
kaolin	-	-	-	R	Aster leafhopper

...continued

Table 9. Insecticides and bioinsecticides registered for disease management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
lambda-cyhalothrin	Pyrethroid, pyrethrin	Sodium channel modulators	3A	RE	Carrot rust fly, carrot weevil
malathion	Organophosphate	Acetylcholinesterase inhibitors	1B	R	Aphids, cabbage looper, imported cabbage worm, spider mites, leaf hoppers, cucumber beetle, flea beetles, pepper weevil
permethrin	Pyrethroid, pyrethrin	Sodium channel modulators	3A	RE	Cutworms: army, black, dark-sided, pale western, red-backed and white
phosmet	Organophosphate	Acetylcholinesterase inhibitors	1B	RE	Carrot weevil
spinetoram	Spinosyn	Nicotinic acetylcholine receptor (nAChR) allosteric activators	5	R	Diamondback moth, cabbage looper, imported cabbageworm
sulfoxaflor	Sulfoxaflor	Nicotinic acetylcholine receptor (nAChR) agonists	4C	R	Aphids
thiamethoxam	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	RE	Aphids, aster leafhopper

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 10, 2014. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (April 2012)* (www.irac-online.org) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review as published in the PMRA *Re-evaluation Note REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

Aster leafhopper (*Macrosteles quadrilineatus*)

Pest information

Damage: Adults and nymphs feed on carrot foliage. This feeding does not cause economic damage but can result in the transmission of the aster yellows phytoplasma. The occurrence of this pest can lead to economic losses when a significant number of leafhoppers carry the phytoplasma and where pest populations are significant. Early detection is needed for control.

Life cycle: The pest winters in weedy areas along field margins and generally moves into carrot fields in early July.

Pest management

Cultural control: Weeds should be removed in surrounding ditches and hedgerows. Other susceptible crops, such as lettuce, should not be planted near the carrot crop. Early seeding increases plant vigour and reduces the chances of infection. Weeds and winter grasses should be controlled in the carrot field. Thresholds, based on the number of leafhoppers present (and not on the number of leafhoppers present that are contaminated with the phytoplasma) have been set at 5 leafhoppers per sample of 25 sweeps.

Resistant cultivars: Resistant cultivars are available.

Chemical control: Insecticides registered for the control of aster leafhopper are listed in table 9.

Issues for aster leafhopper

1. There is a need for a timely, economical, scientific method to determine the percentage of leafhoppers carrying the phytoplasma and to establish thresholds for infected leafhopper populations that warrant control.
2. There is a need to improve monitoring techniques for control of the aster leafhopper.

Wireworms (*Elateridae*)

Pest Information

Damage: Wireworms feed on roots of carrot. Feeding injury reduces the marketability of the crop and can introduce rots.

Life cycle: Adult click beetles lay eggs near the roots of grasses. Upon hatching, the larvae (wireworms) feed on roots in the soil. Adults, larvae and pupae can overwinter. The complete life cycle can take up to six years depending on species.

Pest management

Cultural control: Wireworm populations may be monitored in the fall or early spring using bait stations or by field inspection in the spring. Fields infested with wireworm should be avoided. As wireworms are attracted to pasture and grassland, carrots should not be planted in a field the year after breaking sod. Grass weeds need to be controlled. Cultivation will expose larvae to predators.

Resistant cultivars: None available.
Chemical control: There are no insecticides available for the control of wireworms in carrot.

Issues for wireworms

1. Wireworms are a serious concern with no effective insecticides available for their control. There is a need for new reduced risk products for wireworm control in many root vegetable crops and for alternative strategies to control wireworms.

Carrot weevil (*Listronotus oregonensis*)

Pest information

Damage: Damage, results from larvae tunnelling in roots. Adults also cause injury when they excavate areas for egg laying in young carrots.
Life cycle: Adults overwinter in fields, field margins and ditch banks in the upper 6-8 cm of the soil. Larvae bore down into the roots where they feed for 2-4 weeks before pupating in the surrounding soil. There is only one generation per year in Atlantic Canada, but there may be a second generation in Quebec in some years.

Pest management

Cultural control: Good weed control throughout the year can help control the pest. Planting late will avoid the first generation of weevils in the spring. Removing all carrots and carrot pieces from the field at the end of the season removes breeding sites. There are many naturally occurring beetles and wasps that prey on the on the weevil in the egg, larval and adult stages.
Resistant cultivars: None available.
Chemical control: Insecticides registered for the control of carrot weevil are listed in table 9.

Issues for carrot weevil

1. There is an urgent need for new chemical controls for the carrot weevil.
2. Additional research is needed to develop and facilitate the adoption of alternative, cultural control methods for the carrot weevil.
3. Continued work is required on biological controls for carrot weevil.

Carrot rust fly (*Psila rosae*)

Pest information

Damage: Larvae of the carrot rust fly create tunnels in the roots of carrots, making them unmarketable. Roots may be reduced in size, distorted, scarred and riddled with rust-red burrows of the larvae. Attacks also result in the stunting of carrot plants and seedlings may be killed if the growing tips are severely injured.

Life cycle: The insect overwinters in the pupal stage, with adults emerging from early spring to early summer, depending on location. Females lay eggs on the soil in carrot fields. After hatching, larvae feed on carrot roots. At maturity, larvae leave the roots to pupate in the soil. There may be one, two or a partial third generation per year.

Pest management

Cultural control: Planting close to fields in which carrots were planted the previous year, should be avoided. A 3 year crop rotation should be used. Planting should be delayed until mid-June if possible to avoid the first generation of the pest. Harvesting can be done in late September before damage is incurred in the fall. There are some parasites of the carrot rust fly, however they have not become established in Canada.

Resistant cultivars: None available.

Chemical control: Insecticides registered for the control of carrot rust fly are listed in table 9.

Issues for carrot rust fly

1. There is a need for reduced risk replacement products as well as products with new chemistry for the control of carrot rust fly.
2. Additional research is needed to develop cost effective, alternative, cultural control methods for the carrot rust fly, such as row covers, exclusion fences, sterile flies, baits and deterrent products.

Black cutworm (*Agrostis ipsilon*)

Pest information

Damage: The cutworm feeds at or below the soil surface at night. It is also an active feeder of young foliage and stem tissue and can cut off many young seedlings.

Life cycle: Preferred egg laying sites are low growing vegetation, including chickweed, mustards or plant residue. Heavy spring weed growth, broken sod and crop debris will favour cutworm infestations. There are 3-4 generations per year, with the first generation causing the most damage. The pest is most problematic in low, wet, grassy areas.

Pest management

Cultural control: Crop rotation should be used, avoiding susceptible crops. Planting should not be done in wet, grassy areas. Grassy weeds should be kept under control. Ploughing in the fall will reduce overwintering populations. There are a number of braconid parasites and predaceous ground beetles that can help keep cutworm numbers down.

Resistant cultivars: None available.

Chemical control: Insecticides registered for the control of black cutworm are listed in table 9.

Issues for cutworm

None identified

Weeds

Key Issues

- Linuron is currently under re-evaluation. Depending on the outcome of the re-evaluation, alternative approaches to weed control in carrots may have to be developed.
- There is need to register new herbicides to control crabgrass. This weed is adequately controlled only by group 1 herbicides, for which resistant populations have been identified in Ontario.
- Perennials such as yellow nutsedge and winter annuals are increasing and effective control methods are not available.
- There is a need to register new herbicides for weed control in carrots.

Table 10. Occurrence of weeds in carrot production in Canada[1,2]

Pest	Alberta	Ontario	Quebec	Nova Scotia	Prince Edward Island
Annual broadleaf weeds					
Canada fleabane					
Common ragweed					
Hairy galinsoga					
Kochia					
Lady's-thumb					
Lamb's quarters					
Low cudweed					
Pineapple weed					
Redroot pigweed					
Green pigweed					
Smooth pigweed					
Wild radish					
Wild buckwheat					
Perennial broadleaf weeds					
Canada thistle					
Narrow-leaved goldenrod					
Annual grasses					
Barnyard grass					
Green foxtail					
Wild oats					
Perennial grasses					
Quackgrass					
Other					
Yellow nutsedge					

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and importance.

Pest not present.

Data not reported.

[1]Source: Carrot stakeholders in reporting provinces.

[2]Please refer to Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 11. Adoption of weed management practices in carrot production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Perennial broadleaf weeds	Annual grasses	Perennial grasses	Yellow nutsedge
Avoidance	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	use of weed-free seed					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding)					
	seeding / planting depth					
	water / irrigation management					
	weed management in non-crop lands					
	weed management in non-crop years					
	tillage / cultivation					
Monitoring	scouting - field inspection					
	field mapping of weeds / record of resistant weeds					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
Decision making tools	economic threshold					
	weather/ weather-based forecast/ predictive model					
	recommendation from crop specialist					
	first appearance of weed or weed growth stage					
	observed crop damage					
	crop stage					

...continued

Table 11. Adoption of weed management practices in carrot production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Perennial broadleaf weeds	Annual grasses	Perennial grasses	Yellow nutsedge
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	habitat / environment management					
	ground cover / physical barriers					
	mechanical weed control					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific practices	herbicide banding					
New practices (by province)	manual hoeing (Quebec)					
	hand pulling of weeds (especially common ragweed) (Quebec)					

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
carfentrazone-ethyl	Triazolinone	Inhibition of protoporphyrinogen oxidase (PPO)	14	R	Apply to row middles using hooded sprayers; post-emergence control of broadleaf weeds; lamb's quarters, morning glory, eastern black nightshade, redroot pigweed, velvetleaf, tall waterhemp, round-leaved mallow, hairy nightshade, field pennycress, prostrate pigweed, smooth pigweed, tumble pigweed, common purslane, Pennsylvania smartweed (seedling), tansy mustard, carpetweed, cocklebur, Jimsonweed, kochia, Eastern black nightshade, volunteer canola, glyphosate tolerant volunteer canola, burclover, prickly lettuce, Venice mallow, corn spurry
diclofop-methyl	Aryloxyphenoxy-propionate 'FOP'	Inhibition of acetyl CoA carboxylase (ACCase)	1	R	Wild oats, barnyard grass, foxtails (green, yellow), witchgrass, fall panicum, volunteer corn, silky bentgrass
diquat	Bipyridylium	Photosystem-I-electron diversion	22	R	Weeds; for use pre-emergent to crop, post-emergent to weeds on stale seedbed and inter-row directed weeding
fenoxaprop-p-ethyl	Aryloxyphenoxy-propionate 'FOP'	Inhibition of acetyl CoA carboxylase (ACCase)	1	R	Green and yellow foxtail, barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn
fluazifop-p-butyl	Aryloxyphenoxy-propionate 'FOP'	Inhibition of acetyl CoA carboxylase (ACCase)	1	RES	Annual grasses, quackgrass; volunteer corn, Johnson grass, Persian darnel, barnyard grass, volunteer spring wheat and spring barley, wild oats, wild proso-millet, crabgrass, fall panicum, old witchgrass, green, yellow (wild millet) and giant foxtail, quackgrass, wirestem muhly

...continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
glufosinate-ammonium	Phosphinic acid	Inhibition of glutamine synthetase	10	R	Stale seedbed technique for annual grass and broadleaf weed control: common chickweed, green foxtail, lamb's-quarters, stinkweed, wild mustard, redroot pigweed, dandelion, oak-leaved goosefoot, wild buckwheat
linuron	Urea	Inhibition of photosynthesis at photosystem II	7	RE	Selective control of annual weeds; most annual grasses, common chickweed, corn spurry, goosefoot, groundsel, knotweed, kochia, lamb's-quarters, prostrate pigweed, purslane, ragweed, redroot pigweed, shepherd's purse, smartweed, wild buckwheat, wild radish, wormseed mustard, seedlings of dandelion, plantain and sowthistle, stinkweed (pennycress), annual sowthistle
metribuzin	Triazinone	Inhibition of photosynthesis at photosystem II	5	R	Annual weeds including scentless chamomile, grasses and broadleaf weeds
mineral spirits	not classified	diverse	NC	R	Redroot pigweed, lamb's-quarters, purslane, annual grasses and cottontop
paraquat	Bipyridylium	Photosystem-I-electron diversion	22	RES	Many grasses and broadleaf weeds
prometryne	Triazine	Inhibition of photosynthesis at photosystem II	5	R	Most annual broadleaved weeds and annual grasses including lamb's-quarters, redroot pigweed, wild mustard, purslane, lady's thumb, corn spurry, hemp-nettle, common chickweed, eastern black nightshade, and green foxtail
sethoxydim	Cyclohexanedione 'DIM'	Inhibition of acetyl CoA carboxylase (ACCase)	1	R	Annual grasses, wild oats, volunteer cereals and quackgrass

...continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
s-metolachlor	Chloroacetamide	Inhibition of cell division (Inhibition of VLCFAs)	15	R	American nightshade, eastern black nightshade, crabgrass (smooth, hairy), barnyard grass, redroot pigweed (suppression only), fall panicum, foxtail (green, yellow, giant), old witchgrass, yellow nutsedge
trifluralin	Dinitroaniline	Microtubule assembly inhibition	3	RES	Annual grass and annual broadleaf weeds: wild oats (suppression) foxtail (green, yellow) (wild millet), barnyard grass, crabgrass, bromegrass, cheat, stinkgrass, goosegrass, annual bluegrass, Persian darnel, wild buckwheat (suppression) cowcockle, pigweed, lamb's-quarters, Russian thistle, chickweed, purslane, knotweed, carpetweed

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 7, 2014. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Herbicide Resistance Action Committee (HRAC). *Classification of Herbicides According to Site of Action* (www.hracglobal.com) (accessed January 2014). Herbicide resistance groups are based on the Weed Science Society of America classification system as reported by HRAC.(www.hracglobal.com).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review as published in the PMRA *Re-evaluation Note REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

Annual and Biennial Weeds

Pest information

Damage: Crop losses can be very high if annual weeds are not controlled. Broadleaf weeds can reach heights similar to the carrot crop and compete for light, water and nutrients. If not controlled effectively, they will reduce carrot growth and yield. Annual grasses also cause significant problems in carrot production because of their fast growth and ability to compete for necessary resources. Additionally, grass weeds are very tolerant to extremes in moisture and temperature once established. They can be very difficult to eliminate from infested fields and they require management/control prior to seed-set due to their prolific seeding.

Life cycle: Annual grass and broadleaf weeds complete their life cycle from seed germination through to new seed production, in a single season. Spring annuals germinate in the early spring and produce seed in the summer or fall of the same year. Winter annuals grow to the rosette stage in the fall, maturing and producing seed early the following year. Annual weeds produce large numbers of seeds by which they easily spread. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Biennial weeds are plants that germinate in the spring and produce a rosette of leaves that remains vegetative during the first summer. They overwinter as rosettes and in the next season, they flower and produce seed. The plant dies at the end of the second growing season.

Pest management

Cultural control: A primary preventative measure to control weeds is site selection. Carrots should not be planted in a field for which the weed history is unknown. Fields must be scouted the previous season to determine what weeds might be present and whether they can be controlled in the carrot crop. Difficult to control weed infestations must be reduced to a manageable level before planting the carrot crop. Purchased seed should be certified to ensure that it contains the lowest possible quantities of weed seed. The removal of weeds from fence lines, ditches, and roadways will also help to prevent weed establishment in cropping areas. Weed seeds can be transported from field to field by equipment, wind, water, and animals. To reduce this transport, clean soil and debris from equipment when leaving each field. Manure applications can also introduce weeds to a field. Weed seeds in forages may not be destroyed through digestion by livestock or from composting. Repeated tilling, prior to planting and cultivation after planting, can help reduce the number of germinating weeds that survive. Monitoring for annual weeds should be done during the first 2-3 weeks after weed emergence if post emergence controls are to be applied. Vigorous carrot stands are important to shade out germinating weed seed. Row spacing should be chosen so that row closure is quick. Crop rotation is a very effective method to control all pests including weeds. Planting cover crops, such as winter cereals, can suppress weed growth following crop harvest as well as minimize erosion and nutrient uptake over the winter.

Resistant cultivars: Carrot varieties that give quick emergence and vigorous crop stands will help shade out germinating weed seeds.

Chemical control: Herbicides currently labelled for control in carrots work well on annual grasses and a few small seeded broadleaf weeds. Most annual broadleaf and grass weeds can

be controlled in carrots with a soil applied pre-emergent residual herbicide. This can provide season long protection against germinating weeds and seedlings. Once the carrots emerge, there are limited herbicide options for controlling broadleaf weeds in the crop. Using selective systemic herbicides can control grass that emerges after the crop plants. Herbicides registered for the control of weeds are listed in Table 12.

Issues for annual and biennial weeds

1. Winter annuals are increasing and effective control methods are not available. Current chemical controls offer only "suppression".
2. There is a need to register new herbicides to control crabgrass. This weed is adequately controlled only by group 1 herbicides, for which resistant populations have been identified in Ontario.
3. Linuron is currently under re-evaluation. Depending on the outcome of the re-evaluation, alternative approaches to weed control in carrots may have to be developed.
4. There is a need to register new herbicides for weed control in carrots.

Perennial weeds

Pest information

Damage: Perennial weeds can grow very large and be very competitive, especially if they have been established for several years. This can reduce growth and yield of the crop.

Life cycle: Perennial grass and broadleaf weeds can live for several to many years. Perennials usually flower and produce seeds every year as well as expand their root system, so can spread effectively by both methods. Tillage practices can break up the underground root systems and aid in the spread of perennial weeds. The critical stage for crop damage is early in the growing season, as for annual weeds.

Pest management

Cultural control: Management of perennials is difficult in carrots, especially after the crop has been planted. Prevention is the most important component of any weed management program. The primary preventative measure to control weeds is field selection. It is important to avoid planting carrots into a field that has a history of serious perennial weed problems. Purchased seed should be certified to ensure that it contains the lowest possible quantities of weed seed. The removal of weeds from fence lines, ditches, and roadways will also help to prevent weed establishment in cropping areas. Cultivation is less effective in controlling perennial weeds as compared to annual weeds. Cultivation may actually break up the underground portions of the plant and increase the weed problem. Weed seeds and other reproductive parts such as roots and rhizomes can be transported from field to field by equipment, wind, water, and animals. Equipment should be cleaned of all soil and debris when leaving each field, to reduce spread. Crop rotation is a very effective method to control weeds. Crop rotation can disrupt perennial weed life cycles by allowing a variety of control options and cultural practices that discourage normal weed growth. Planting cover crops, such as winter cereals, can suppress weed growth following crop harvest as well as minimize erosion over the winter.

Resistant cultivars: Carrot varieties that give quick emergence and vigorous crop stands will help shade out germinating weed seeds.

Chemical control: Many perennial broadleaf and grass weeds cannot be effectively controlled once established in the carrot crop. Herbicides registered for the control of weeds are listed in Table 12.

Issues for perennial weeds

1. Perennials such as yellow nutsedge are increasing and effective control methods are not available. Current chemical controls offer only "suppression".

Vertebrate Pests

There are a few vertebrate pests than can affect carrots. Groundhogs can destroy seedlings in the spring and deer can eat roots, being very destructive in fall.

Resources

IPM/ICM resources for production of carrot in Canada

Atlantic Provinces Agricultural Services Coordinating Committee. 1997. *Vegetable Crops Production Guide for the Atlantic Provinces*. Publication 1400 Atlantic Provinces Agricultural Services Coordinating Committee.

Websites

Agri-Reseau http://www.agrireseau.qc.ca

Sage PesticideB http://www.sagepesticides.qc.ca/default.aspx

http://eap.mcgill.ca/agrobio/ab360-12.htm#Dommages

Health Canada, Pest Management Regulatory Agency http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php

Ontario Ministry of Agriculture and Food – Vegetables: Roots and bulbs, carrot, garlic, horseradish, leek, onion, parship, raddish, rutabaga, shallots, sugarbeet, sweet potato, table beet http://www.omafra.gov.on.ca/english/crops/hort/root_crops.html

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Howard, R.J., J.A. Garland and W.L. Seaman. Ed. (1994*). Diseases and Pests of Vegetable Crops in Canada*. Canadian Phytopathological Society and Entomological Society of Canada. Ottawa, ON. 554pp.

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 75, Guide to Weed Control 2012-13. 2012. http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm

Ontario Ministry of Agriculture and Food. Publication 700, Integrated Pest Management of Onions, Carrots, Celery and Lettuce in Ontario http://www.omafra.gov.on.ca/english/crops/pub700/p700order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Vegetable Production Recommendations (2009-10) Publication 363);* Publication 363SE, Supplement - Vegetable Production Recommendations 2010-2011 http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario Vegetable Crop Protection Guide (2012-13) Publication 838[E] (www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Perennia. Guide to Pest Management in Carrots – Nova Scotia Vegetable Crop Guide to Pest Management 2013 [CAR1-13] Updated April 2nd, 2013
http://www.perennia.ca/Pest%20Management%20Guides/Vegetables/2013/Carrots%202013.pdf

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Alberta	Alberta Agriculture and Rural Development www.agric.gov.ab.ca/	Patricia McAllistair tricia.mcallister@gov.ab.ca	Jim Broatch jim.broatch@gov.ab.ca
Ontario	Ontario Ministry of Agriculture and Food www.omafra.gov.on.ca	Marion Paibomesai marion.paibomesai@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Mario LeBlanc mario.leblanc@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture and Fisheries Perennia www.perennia.ca	Viliam Zvalo Vzvalo@perennia.ca Rachael Cheverie Rcheverie@perennia.ca	Steven Tattrie tattrisc@gov.ns.ca
Prince Edward Island	Prince Edward Island Department of Agriculture and Forestry www.gov.pe.ca/af	Susan MacKinnon sdmakinnon@gov.pe.ca	Shauna Mellish smmellish@gov.pe.ca

National and Provincial Carrot Grower Organizations

Provincial

Conseil Québecois de l'horticulture (CQH) http://www.cqh.ca

Horticulture Nova Scotia http://hortns.com

Ontario Fruit and Vegetable Growers Association http://www.ofvga.org

Prince Edward Island Horticultural Association peihort@pei.aibn.com

National

Canadian Horticultural Council http://www.hortcouncil.ca

Appendix 1

Definition of terms and colour coding for pest occurrence table of the crop profiles.

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 11 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and importance in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="6">**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>**Moderate** - If present, potential for spread and crop loss is moderate; pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>**Low** - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">**Localized** - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="6">**Sporadic** - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - as above</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>Yellow</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="3">**Localized** - as above</td><td>**High** - see above</td><td>Yellow</td></tr>
<tr><td>**Moderate** -see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data **not** available</td><td colspan="3">**Not of concern:** The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">**Is of concern:** The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>grey</td></tr>
</table>

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http://publications.gc.ca/site/eng/home.html

Ontario Ministry of Agriculture and Food. Managing Wireworms in Vegetable Crops Agdex 250/625 http://www.omafra.gov.on.ca/english/crops/facts/00-047.htm